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The Effect of Strengthening Exercises on Exaggerated Muscle Tonicity in Chronic Hemiparesis Following Stroke

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The purpose of this study was to determine quadriceps and gasterosoleous muscles tonicity problems in hemiparetic patients and the effects of strengthening exercises protocol in treatment of these impairments. In 2004, a clinical randomized trial was conducted in Tehran province, Iran. Thirty four-hemiparetic patients secondary to stroke aging 49.05±6.19 years participated in this trial. Patients were assigned randomly to either an experimental group or a control group and muscle strength (kg) were measured using hand held dynamometer and their muscle tone (ordinal) was graded on the Modified Ashworth Scale (MAS) before and after 12 sessions of intervention. The experimental group received functional, balance and strengthening exercises protocol. The control group received functional and balance exercises protocol. In experimental group measure of quadriceps and gastrosoleous tonicity decreased from 1.88±1.05 to 0.82±0.88 and 3.06±1.43 to 1.65±1.11, respectively ($p<0.0001$). Treatment was reduced gastrosoleous tone from 3.23± 1.15 to 3±1 in the control group ($p= 0.041$). Tonicity of both muscles decreased in the experimental group compared to the control group ($p<0.0001$). Present results, in contrary with current opinions, support the effectiveness of lower limb muscle strength training to reduce the spasticity in addition to improving muscle strength in the chronic stage of stroke.

Key words: Tonicity, exercises, stroke, MAS

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INTRODUCTION

Stroke is the most common cause of adult disability after heart disease and cancer (Anderson *et al.*, 1993). Stroke is defined as a sudden, focal neurological deficit resulting from ischemic or haemorrhagic lesions in the brain, which lasts more than 24 h (O'Sullivan, 1994). There are different reports about residual disability in patients who survived after stroke (O'Sullivan, 1994; Anderson *et al.*, 1993; Duncan *et al.*, 1994). The high prevalence (29.8%) of stroke and its high economic costs make the reduction of stroke- related activity limitation a national health care priority (Stineman and Granger, 1998). The disability resulting from stroke is most commonly presented as hemiplegia or hemiparesis (Bobath, 1979). Although the variety and severity of the impairment is dependent on the site and extent of the lesion (O'Sullivan, 1994), one of the most common problems resulting from stroke is muscle and postural tonicity impairments (O'Sullivan, 1994; Ghes, 1991). The range of muscle tone abnormalities found within patients is broad. At lower end of the tone spectrum is flaccidity and on the upper end of it, is spasticity (Shumway Cook and Woollacott, 1995).

There is still no agreement on the role of spastic hypertonicity in the loss of functional performance (Katz and Rymer, 1989). A few research studies showed that spastic hypertonicity limits a patient's ability to move quickely, since activation of stretch reflex is velocity dependent (Bohannon and Smith, 1987). Bobath (1979) suggests that "Weakness of muscles may not be real, but relative to the opposition of spastic antagonists" and have proposed that normalization of muscle tone should be a priority of treatment. Other studies have found evidence against this argument. Instead researchers are suggesting that inadequate recruitment of agonist motoneurons (weakness), not increased activity in the antagonist, is the primary cause for disorders of motor control following upper motor lesions (Whitley *et al.*, 1982). Thus, other problems such as dyssynergia and weakness affects motor control ability rather than hypertonicity (Katz and Rymer, 1989). Other studies suggest that muscle weakness is, at least in part, the consequence of decreased force output by the agonist motor units (Tang and Rymer, 1981). Bohannon et al showed that an agonist muscle capacity for force production is in light of its own tone rather than that of its antagonist (Bohannon *et al.*, 1987). Karimi (1996) reported the effectiveness of an isokinetic program in testing and training of weak muscles of hemiparetic subjects without increasing the spasticity. Weiss *et al.* (2000) showed that strength training is an appropriate intervention to improve the quality of physical function in stroke survivors.

In the most studies, assessment and therapeutic approaches was focused on the acute stage of the problem. In addition, the conventional methods were not successful in treating of tonicity impairments, especially in the chronic stage of the disease. As well, the results of studies showed that these problems were seen in more than 50% of survivors (Anderson *et al.*, 1993, Stineman and Granger, 1998) and also controversy exists with regard to the appropriateness of muscle strength testing and training, thus determination of tonicity impairments and appropriate recovery method of these impairments are necessary.

Although weakness and spasticity are two different signs of upper motor neuron lesion, but lack of strength in this subjects was not considered. Thus, a combined physiotherapy program was designed consisting of functional, balance and strengthening exercises for treatment of impairments on the principles of motor control, motor learning, postural control and principles of muscle strengthening. The main properties of these exercises protocol is application of strengthening and endurance exercises in addition to conventional methods. The aim of this study was two folded; first, to determine and comparison of the muscle tonicity between pre treatment and post treatment findings with two protocols, with and without strengthening exercises and the second, to determine interrater reliability of Modified Ashworth Scale in evaluating the results of two exercise protocols in hemiparetic subjects one year after stroke. We hypothesized that muscle tonicity was reduced after treatment with strengthening protocol and this protocol is more effective in tonicity reduction than other protocol.

MATERIALS AND METHODS

Subjects: This clinical trial was performed in 2004. Participants were recruited from the Kahrizak Charity Foundation and through an approach to the consultant neurologist. All patients were screened to ensure that their time since onset of stroke was at least 12 months. Prior to commencement of the study, approvals were sought from the Ethic's Committee and the Research Council of Tarbiat Modarres University. The purpose of the study and testing protocol to be used were explained to the subjects and an informed and written consent document was obtained from all participants. Subjects were blinded to their group allocation and remained blinded. Also the individuals were blinded to the aims and hypotheses of the study. The pilot study performed on ten hemiparetic subjects and in two control and experimental groups determined that a total of 15 subjects were necessary for each group. Forty two subjects, suffering from hemipaersis secondary to stroke participated in this clinical trial through simple non-probability sampling. None of these patients used of walking aids in the evaluation and treatment period. Thirty-four Patients were selected according to the following inclusion criteria: (1) at least one year after stroke, (2) age between 40 to 60 years, (3) hemiparesis secondary to stroke, (4) able to stand at least 30 seconds with eyes open and separate feet, (5) able to understand instructions and follow simple directions, (6) no other physiotherapy program during this study. Patients with second stroke, bilateral involvements, lower limb arthritis, significant visual field deficit, severe perceptual aphasia and surgery of CNS and neuromuscular and other musculoskeletal disease of the lower limb were excluded. Patients were assigned randomly to either an experimental or a control group.

Methods: Data were collected through interview, inspection and examination. After obtaining history of the disease and characteristics of patients, the visual field was tested by confrontation test. Isometric strength (kg) of seven muscle groups was measured using hand-held dynamometer and their quadriceps and gastrosoleous tone was graded on the Modified Ashworth Scale (ordinal) before and after 12 sessions of intervention by two rater (Bohannon *et al*., 1987; Gregson *et al*., 1999, 2000). The highest score was recorded for each subject by two raters, independently. Two raters were blinded to the group allocation and to the results of the other rater. Isometric strength of hip flexors, knee flexors and extensors and ankle dorsiflexors was measured in sitting position and hip, knee and ankle joints in right angle, hip extensors in side lying position, hip abductors in supine and plantarflexors in prone position and knee and ankle joints in right angle (Hislop and Motgomery, 1995). During the isometric testing the dynamometer was attached to distal end of the moving bone. These methods have intrerater reliability. Treatment was commenced just after assessments and final assessments were completed at the end of treatment.

Both groups received treatment for 12 sessions (4 weeks and 3 times per week) and approximately 3 h per session. All subjects tolerated the three-hour exercises protocol with brief resting during training (Wang, 1994). Any adverse effects were not seen. All exercises were repeated ten times in one session for each group. The experimental group received functional, balance and strengthening protocol that is a combination of three parts. First part: consists of 23 standing, 3 sitting balance, 58 functional mobility, 21 gait patterns and an aerobic fitness exercises. Second part consisted of 8 functional exercises on the principle of selective movements that included squatting, hiking, bridging, dropping, toe and heel walking, lower limb extension, alternating flexion and extension of lower limbs and tilting reaction. Third part of the protocol included strengthening of sagital and frontal plane muscles affected in gait. The one repetition maximum was determined using dynamometer for strengthening of flexor, abductor and extensor muscle groups of hip, flexor and extensor groups of knee and dorsiflexor and plantarflexor groups of the ankles on the affected side. Concentric isotonic type of contraction with 70% of 1RM was used for strengthening these muscles. Very weak muscles trained using synergism and motor imagery patterns. The control group received all exercises protocol except for strengthening exercises. Finally, all patients were assessed and results recorded by two raters.

Statistical analysis: Data were analyzed using SPSS9. Kolmogorov-Smirnov test for normality were performed for all outcome variables. For parametric data independent and paired t-tests were used for comparison between pretreatment and post treatment test results between groups and within groups, respectively. For nonparametric data Mann- Whitney and Wilcoxon tests were used for comparison between pretreatment and post treatment test results between groups and within groups, respectively. Intraclass correlation coefficient (ICC's) was used to investigate the relationship between the scores of the two raters. The level of significance was set at $p<0.05$.

RESULTS

The mean age of 17 subjects of experimental group was 49.3±7.1 years and their time post stroke was 34.5±26.37 months. The 7 female and 10 male, 8 right and 9 left hemiparesis participated in this group. The mean of quadriceps and gastrosoleous tonicity was 1.88±1.05 and 3.06±1.43, respectively. The mean age of 17 subjects of control group was 48.8± 3 years and their time post stroke was 35.3±27.5 months. The 8 female and 9 male, 5 right and 12 left hemiparesis participated in this group. The mean of quadriceps and gastrosoleous tonicity was 1.7±1.21 and 3.23±1.15, respectively.

We first examined interrater reliability. The scotterplot chart showed linear relationship between results of two raters in both pretreatment and post treatment scores.

Pretreatment scores of quadriceps tonicity from both raters were correlated (ICC= 0.97; 95% CI 0.94 to 0.98), as did post treatment scores (ICC= 0.96; 95% CI 0.93 to 0.98). Pretreatment scores of gastrosoleous tonicity from both raters were correlated (ICC = 0.97; 95% CI 0.94 to 0.98), as did post treatment scores (ICC= 0.97; 95% CI 0.94 to 0.98).

The comparisons were made within two groups to investigate the effects of both protocols and mean differences between pretreatment and post treatment tests were calculated and compared. Discussion and conclusion about each variable was performed only according to mean difference comparisons results.

Tonicity: The quadriceps tonicity only in the experimental group decreased from 1.88±1.05 to 0.82±0.88 ($p<0.0001$), but treatment was not effective in control group ($p = 0.055$). The gasterosoleous tonicity decreased from 3.06±1.43 to 1.65±1.11 ($P<0.0001$) and 3.23±1.15 to 3±1 ($p = 0.041$) in the experimental and control groups, respectively. Significant reduction after treatment was seen in the experimental group in measures of quadriceps ($p = 0.034$) and gasterosoleous ($p = 0.001$) tonicity compared to control group. The Mann-Whitney test also identified a significant difference between the experimental group and the control group with respect to mean difference of quadriceps ($p<0.0001$) and gasterosoleous ($p<0.0001$) tonicity.

Strength: All muscles' strength of unaffected lower extremity in the experimental group increased after intervention ($p<0.0001$). Intervention was not effective in control group except for hip and knee extensors ($p<0.0001$) and ankle dorsiflexors ($p = 0.008$). The mean difference of all muscles except for knee extensors ($p = 0.184$) increased in the experimental group compared to the control group ($p<0.0001$).

All muscles' strength of affected lower extremity in the experimental group increased after intervention ($p<0.0001$), but intervention was not effective in control group except for hip ($p = 0.003$) and knee ($p<0.0001$) extensor muscles. The experimental group received all exercises protocol. The control group received all protocol except for strengthening exercises.

DISCUSSION

The findings showed that both protocol in the chronic stage of stroke have decreased gastrosoleous tonicity. As well, the effect of functional, balance and strengthening exercises protocol in reduction of quadriceps tonicity was significant. Comparing of the mean difference and after treatment results showed a significant reduction in both muscle tonicities of the experimental group compared to the control group. The major finding was that adding strengthening exercises to functional and balance protocol resulted in significant reduction of muscle tonicity in both muscles. In spite of current opinion, our findings revealed that muscle strengthening exercises not only did result in increased tonicity, but also decreased the hypertonicity. Present findings showed that strengthening exercises resulted in increased muscle strength and agonist strength did not dependent on the hypertonicity of the antagonist. Quadricpes tonicity was reduced 56 and 7%, as did gastrosoleous tonicity 46 and 7% in experimental and control group, respectively. Our findings also suggest that Modified Ashworth Scale had the capability of muscle tonicity assessment in the chronic stage of stroke and its interrater reliability was good.

The most common controversy in hemiparesis following upper motor neuron lesion is the different approach of researchers to muscle exaggerated tonicity. Some methods of stroke rehabilitation have focused on the reduction of abnormal reflex activity and movement. It has been suggested that hypertonicity of antagonist is the primary cause of motor dyscontrol and has been proposed that normalization of muscle tone should be a priority of treatment (Bobath, 1979; Bohannon *et al*., 1987). Katz *et al*., (1989) emphasized the role of stretch reflex on disability. However, there is no agreement on the roll of spastic hypertonia in loss of functional performance. The presumption was that spasticity limits the patient's ability to move quickly, since stretch reflex is velocity dependent (Bohannon and Smith, 1987). Present results were not agreement with this argument. Instead we are suggesting that inadequate recruitment of agonist motoneurons and not increased activity in the antagonist, is the primary cause for disorders of motor control following upper motor neuron lesions. Thus, emphasize on the muscle strengthening and coordination is more effective in functional independence (Whitley *et al*., 1982; Tang and Rymer, 1981). The relationship between muscle weakness and spasticity was not found (Bohannon *et al*., 1987). Present findings revealed that muscle strengthening exercises not only did not result in increased tonicity but also decreased the hypertonicity. Reduction of quadriceps tonicity in control group was not significant. Our findings showed that strengthening exercises resulted in increased muscle strength, therefore, emphasize on dependence of agonist strength on the hypertonicity of the antagonist may not be substantiated. Other studies suggested that strengthening exercises did not cause any change in the level of spasticity (Karimi, 1996; Teixeira Salmela *et al*., 1999). McLellan (1977) suggested that abnormal muscle stretch reflexes are not an intrinsic cause of disability. He found that abnormal muscle co-contraction persisted, even when stretch reflexes were reduced by the administration of baclofen. Bohannon *et al*. (1987) showed that static strength deficit of medial rotators of shoulder and flexors of elbow were strongly correlated with their antagonist spasticity. Gregson *et al*. (1999) reported that the interrater reliability of Modified Ashworth Scale except for plantarflexor mscles that is moderate to good, in flexor and extensor muscles of elbow, wrist, knee and ankle joint is very high.

The strength of flexor, extensor and abductor muscle groups of hip, flexor and extensor muscle groups of knee and dorsiflexor and plantarflexor muscle groups of ankle in sound lower limb was compared. In control group hip, knee and ankle extensor muscles' strength increased after treatment. Higher improvement was seen in knee extensor muscles. Other muscles did not show any change. In experimental group strength of all muscle groups increased with higher increase in knee extensor groups. Significant strength improvement was seen in experimental group compared to control group. The comparison of mean difference in all muscle groups except for knee extensor groups revealed significant improvement in experimental group. To prevent collapse during the stance phase of gait, some of the muscles of the supporting lower limb contract to create an extensor moment. Although the stance phase extensor moment can be produced by any combination of hip, knee and ankle extensor muscle activity, the knee extensor muscles normally make a major contribution to the total extensor moment (Winter, 1980). Some exercises of our protocol can cause hypertrophy in addition to synchronization of motor units (Spielholz, 1990; Yue and Cole, 1992). In addition, strength training can lead to the phenomenon of 'cross education' whereby movements contralateral to the trained limb exhibit increased strength (Yue and Cole, 1992). The role of strengthening exercises along with balance and functional exercises in improvement of muscle strength on the affected side of hemiparetic patients were investigated. In experimental group significant improvement of muscle strength was seen after treatment, however, in control group only increase in knee and hip extensor muscles' strength was significant. Higher improvement in experimental group was in hip flexors and in control group in knee extensors. The strength improvement in experimental group compared to control group was significant and this may be attributed to additional exercises.

Strength results from both properties of muscle itself and the appropriate recruitment of motor units and the timing of their activation (Shumway Cook and Woollacott, 1995). In prescribing exercise for hemiparetic patients above aspects should be considered. The effect of the present exercise protocol was on both the central set and the actuator. Exercise affects the muscle characteristics. The muscle work is not dependent on the instant input, but is dependent on the previous works. The affected part in memorization of hysteresis is the "force generator system", which is triggered by chemical, electrical and mechanical forces. The muscles use this memory in next works. The central effects of exercises are due to motor learning (Shumway Cook and Woollacott, 1995). Physiological plasticity associated with recovery of function is the same that is affected in learning. Thus, practice and experience can result in reorganization of central nervous system. Motor learning and consequent changes of synaptic connections are activity-dependent. These evidences suggest that our sensory and motor maps in the cortex are constantly changing in accordance with the amount to which they are activated by peripheral inputs. In addition, experience is very important in shaping cortical maps (Shumway Cook and Woollacott, 1995). Other studies demonstrated that the development of skilled movement, but not increased strength, was associated with a reorganization of movements' representation within motor cortex (Remple *et al*., 2001). A third group of authors believe that passive movements in hemiparetic stroke patients elicit some of the brain activation patterns after substantial brain recovery (Nelles *et al*., 1999). Whereas there is evidence for training induced changes in neural function within the spinal cord including increased motor unit recruitment (Bernardi *et al*., 1996) and motoneuron excitability (Sale *et al*., 1983), other work has implicated supraspinal motor structures (Yue and Cole, 1992). Some studies suggest that strengthening exercises results in adaptation in central nervous system (Evarts, 1968) and exercises can strengthen without any increase in muscle mass (Hakkinen *et al*., 1988).

This study has two implications for clinical practice; first, the functional, balance and strengthening protocol is more effective in reduction of quadriceps and gastrosoleous tonicity than the protocol without strengthening exercises. In two previous studies (Karimi, 1996; Teixeira Salmela *et al*., 1999), only showed that strengthening exercises has not been any adverse effect on muscle tonicity and decrease of tonicity as a result of these exercises was not reported. Second, the measurement of strength and tonicity is beneficial in evaluation of tonicity impairments in chronic stages of hemiparesis following stroke and the independent variables are appropriate targets for therapeutic interventions.

In conclusion, the results of this study showed that, in spite of reduction of hypertonicity, further research about type, intensity, frequency and duration of strengthening exercises is necessary.

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